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East Vermillion Lake McCook County South Dakota

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U.S. ENVIRONMENTAL PROTECTION AGENCY
NATIONAL EUTROPHICATION SURVEY

WORKING PAPER SERIES

REPORT
ON
EAST VERMILLION LAKE
McCOOK COUNTY
SOUTH DAKOTA
EPA REGION VIII
WORKING PAPER No. 626

CORVALLIS ENVIRONMENTAL RESEARCH LABORATORY - CORVALLIS, OREGON
and
ENVIRONMENTAL MONITORING & SUPPORT LABORATORY - LAS VEGAS, NEVADA

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REPORT

ON

EAST VERMILLION LAKE

McCOOK COUNTY

SOUTH DAKOTA

EPA REGION VIII

WORKING PAPER No. 626

WITH THE COOPERATION OF THE

SOUTH DAKOTA DEPARTMENT OF ENVIRONMENTAL PROTECTION

AND THE

SOUTH DAKOTA NATIONAL GUARD

DECEMBER, 1976

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16. ABSTRACT

Annual total phosphorus and total nitrogen loadings to the lake were estimated and subdivided according to either point or non-point source origin. An assessment of the lake's trophic condition and limiting nutrient is also provided. All data collected by the U.S.E.P.A. National Eutrophication Survey during the one year study of the lake and its tributaries are included in the report.

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FOREWORD

The National Eutrophication Survey was initiated in 1972 in response to an Administration commitment to investigate the nationwide threat of accelerated eutrophication to freshwater lakes and reservoirs.

OBJECTIVES

The Survey was designed to develop, in conjunction with state environmental agencies, information on nutrient sources, concentrations, and impact on selected freshwater lakes as a basis for formulating comprehensive and coordinated national, regional, and state management practices relating to point-source discharge reduction and non-point source pollution abatement in lake watersheds.

ANALYTIC APPROACH

The mathematical and statistical procedures selected for the Survey's eutrophication analysis are based on related concepts that:

a. A generalized representation or model relating sources, concentrations, and impacts can be constructed.

b. By applying measurements of relevant parameters associated with lake degradation, the generalized model can be transformed into an operational representation of a lake, its drainage basin, and related nutrients.

c. With such a transformation, an assessment of the potential for eutrophication control can be made.

LAKE ANALYSIS

In this report, the first stage of evaluation of lake and watershed data collected from the study lake and its drainage basin is documented. The report is formatted to provide state environmental agencies with specific information for basin planning [§303(e)], water quality criteria/standards review [§303(c)], clean lakes [§314(a,b)], and water quality monitoring [§106 and §305(b)] activities mandated by the Federal Water Pollution Control Act Amendments of 1972.

Beyond the single lake analysis, broader based correlations between nutrient concentrations (and loading) and trophic condition are being made to advance the rationale and data base for refinement of nutrient water quality criteria for the Nation's freshwater lakes. Likewise, multivariate evaluations for the relationships between land use, nutrient export, and trophic condition, by lake class or use, are being developed to assist in the formulation of planning guidelines and policies by EPA and to augment plans implementation by the states.

ACKNOWLEDGMENT

The staff of the National Eutrophication Survey (Office of Research & Development, U. S. Environmental Protection Agency) expresses sincere appreciation to the South Dakota Departments of Environmental Protection and Game, Fish and Parks for professional involvement, to the South Dakota National Guard for conducting the tributary sampling phase of the Survey, and to those wastewater treatment plant operators who voluntarily provided effluent samples.

Allyn Lockner, Secretary, and Blaine Barker and Duane Murphy, Department of Environmental Quality; Douglas Hansen, Department of Game, Fish and Parks; and James Hayden, Director, State Lakes Preservation Committee provided invaluable lake documentation and counsel during the Survey, reviewed the preliminary reports, and provided critiques most useful in the preparation of this Working Paper series.

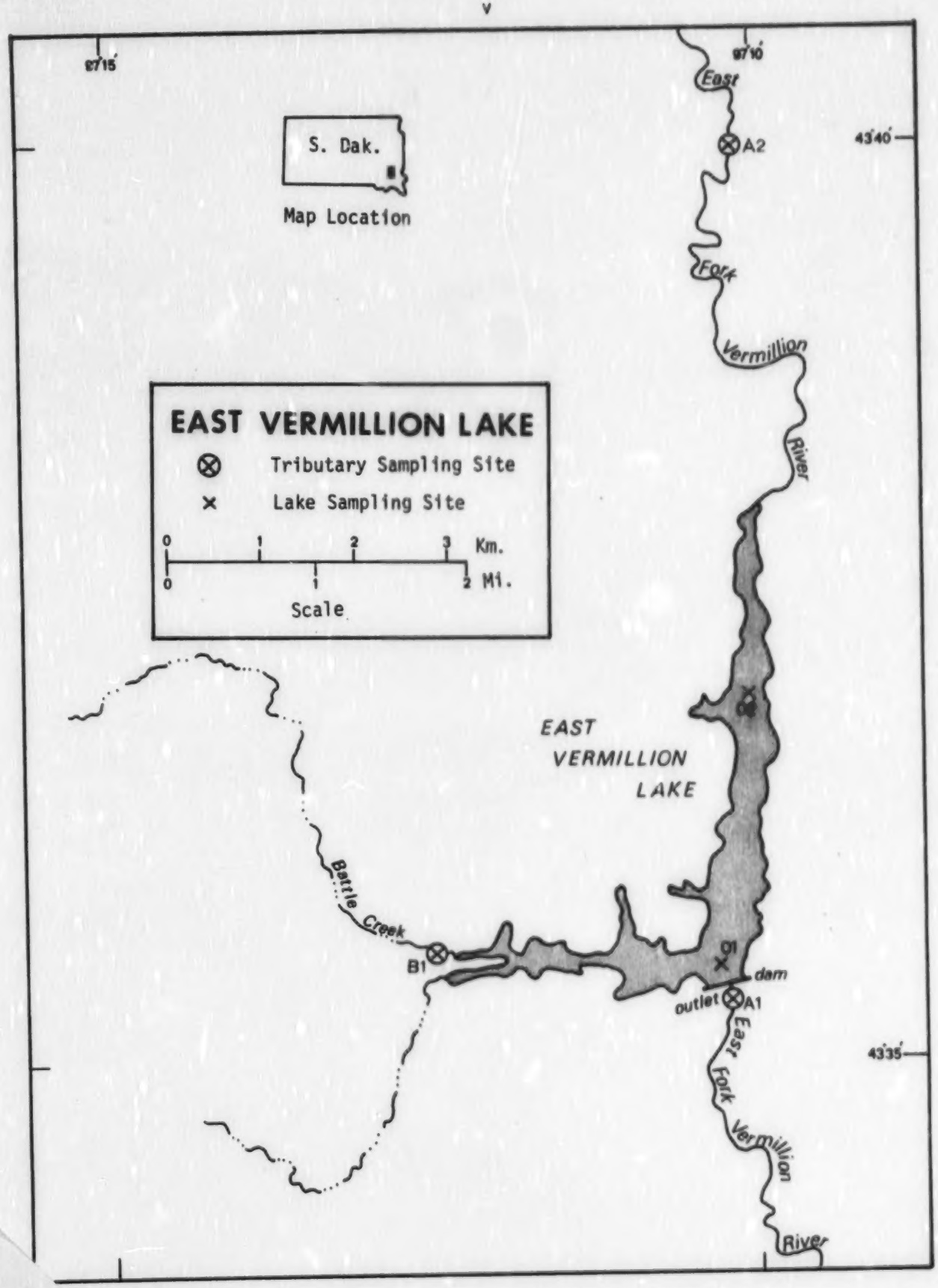
Major General Duane L. Corning, the Adjutant General of South Dakota, and Project Officer Colonel Robert D. Chalberg, who directed the volunteer efforts of the South Dakota National Guardsmen, are also gratefully acknowledged for their assistance to the Survey.

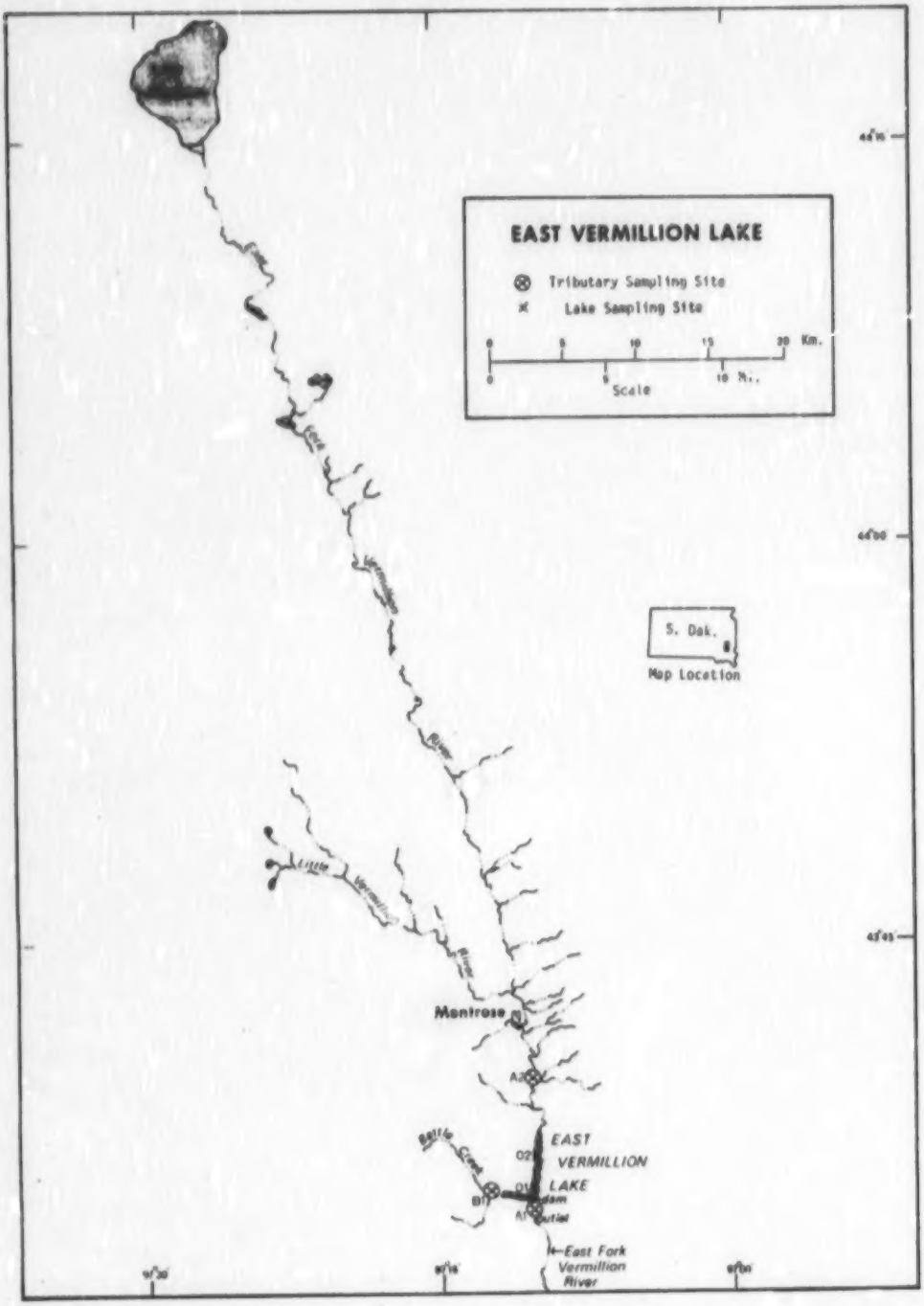
NATIONAL EUTROPHICATION SURVEY

STUDY LAKES

STATE OF SOUTH DAKOTA

LAKE NAME	COUNTY
Albert	Kingsbury
Alvin	Lincoln
Angostura	Fall River
Brant	Lake
Byron	Beadle
Clear	Marshall
Clear	Minnehaha
Cochrane	Deuel
Cottonwood	Spink
Deerfield	Pennington
Enemy Swim	Day
Herman	Lake
John	Hamlin
Kampeska	Codington
Madison	Lake
Mitchell	Davidson
Norden	Hamlin
East Oakwood	Brookings
West Oakwood	Brookings
Pactola	Pennington
Pickerel	Day
Poinsett	Brookings, Lake
Red Iron South	Marshall
Richmond	Brown
Roy	Marshall
Sand	Brown
Sheridan	Pennington
Stockdale	Custer
East Vermillion	McCook
Wall	Minnehaha
Waubay	Day


97°15'
97°10'
East
A2
43°40'
S. Dak.
Map Location
Fork
Vermillion
River
EAST VERMILLION LAKE
Tributary Sampling Site
Lake Sampling Site
0 1 2 3 Km.
0 1 2 Mi.
Scale
EAST
VERMILLION
LAKE
Battle Creek
B1
01
dam
outlet
A1
East Fork Vermillion
River
43°35'


EAST VERMILLION LAKE
Tributary Sampling Site
Lake Sampling Site
0 5 10 15 20 Km.
0 5 10 Mi.
Scale
S. Dak.
Map Location
44°45
44°30
43°45
Montrose
A2
EAST
VERMILLION
LAKE
Dam
Outlet
East Fork
Vermillion
River

EAST VERMILLION LAKE

STORET NO. 4629

I. CONCLUSIONS

A. Trophic Condition:

Survey data indicate that East Vermillion Lake is eutrophic. It ranked sixteenth in overall trophic quality when the 31 South Dakota lakes sampled in 1974 were compared using a combination of six lake parameters*. Nineteen of the lakes had less median total phosphorus, 20 had less median dissolved phosphorus, nine had less median inorganic nitrogen, 22 had less mean chlorophyll a, and 21 had greater mean Secchi disc transparency.

Survey limnologists observed heavy blooms of filamentous algae in July and September.

B. Rate-Limiting Nutrient:

The results of the algal assays indicate that East Vermillion Lake was nitrogen limited when the assay samples were taken (04/22/74 and 09/20/74).

The lake data indicate nitrogen limitation all three sampling times.

C. Nutrient Controllability:

1. Point sources--No known municipal or industrial point sources impacted East Vermillion Lake during the sampling year. Septic tanks serving lakeshore dwellings and a picnic area were

* See Appendix A.

estimated to have contributed 0.8% of the total phosphorus load, but a shoreline survey would be necessary to determine the actual significance of those sources.

The present phosphorus loading of 0.30 $g/m^2/yr$ is about 1.4 times that proposed by Vollenweider (Vollenweider and Dillon, 1974) as a eutrophic loading (see page 11). However, a significant reduction in the phosphorus loading would be difficult to accomplish because of the large non-point-source contribution.

2. Non-point sources--Non-point sources accounted for 99.2% of the total phosphorus load reaching the lake during the sampling year. The Vermillion River contributed 79.5% of the total load, and the ungaged tributaries contributed an estimated 13.6%.

The phosphorus export rate of the Vermillion River was less than 1 $kg/km^2/yr$ (see page 10). This rate is low compared to the rates of the tributaries of other South Dakota lakes.

II. LAKE AND DRAINAGE BASIN CHARACTERISTICS†

A. Lake Morphometry††:

1. Surface area: 2.23 kilometers^2.
2. Mean depth: 3.7 meters.
3. Maximum depth: 7.0 meters.
4. Volume: 8.251 x 10^6 m^3.
5. Mean hydraulic retention time: 2.8 years.

B. Tributary and Outlet:
(See Appendix C for flow data)

1. Tributaries -

Name	Drainage area (km^2)*	Mean flow (m^3/sec)*
Vermillion River	932.4	0.081
Minor tributaries & immediate drainage -	101.4	0.014
Totals	1,033.8	0.095

2. Outlet -

Vermillion River	1,036.0**	0.092

C. Precipitation***:

1. Year of sampling: 42.9 centimeters.
2. Mean annual: 60.1 centimeters.

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† Table of metric conversions--Appendix B.
†† Murphey, 1974.
* For limits of accuracy, see Working Paper No. 175, "...Survey Methods, 1973-1976".
** Includes area of lake.
*** See Working Paper No. 175.

III. LAKE WATER QUALITY SUMMARY

East Vermillion Lake was sampled three times during the open-water season of 1974 by means of a pontoon-equipped Huey helicopter. Each time, samples for physical and chemical parameters were collected from one or more depths at two stations on the lake (see map, page v). During each visit, a single depth-integrated (near bottom to surface) sample was composited from the stations for phytoplankton identification and enumeration; and during the first and last visits, a single 18.9-liter depth-integrated sample was composited for algal assays. Also each time, a depth-integrated sample was collected from each of the stations for chlorophyll a analysis. The maximum depths sampled were 4.6 meters at station 1 and 3.4 meters at station 2.

The sampling results are presented in full in Appendix D and are summarized in the following table.

A. SUMMARY OF PHYSICAL AND CHEMICAL CHARACTERISTICS FOR LAKE VERMILLION
STORET CODE 4629

PARAMETER	1ST SAMPLING (4/22/74) 2 SITES RANGE	MEAN	MEDIAN	2ND SAMPLING (7/11/74) 2 SITES RANGE	MEAN	MEDIAN	3RD SAMPLING (9/20/74) 2 SITES RANGE	MEAN	MEDIAN
TEMP (C)	10.8 - 10.9	10.8	10.8	24.3 - 25.6	25.0	25.0	16.6 - 17.1	16.9	17.1
DISS OXY (MG/L)	9.0 - 9.4	9.2	9.3	5.8 - 10.2	8.7	9.2	9.2 - 10.6	9.7	9.4
CNDCTVY (MCROMO)	385. - 545.	467.	454.	822. - 826.	824.	824.	687. - 699.	694.	695.
PH (STAND UNITS)	****** - **********			8.9 - 9.3	9.1	9.1	9.2 - 9.3	9.3	9.3
TOT ALK (MG/L)	151. - 155.	153.	153.	133. - 148.	140.	139.	147. - 149.	148.	149.
TOT P (MG/L)	0.079 - 0.101	0.088	0.087	0.174 - 0.301	0.238	0.231	0.254 - 0.303	0.277	0.275
ORTHO P (MG/L)	0.011 - 0.020	0.013	0.011	0.092 - 0.124	0.104	0.101	0.087 - 0.112	0.098	0.094
NO2+NO3 (MG/L)	0.030 - 0.130	0.050	0.035	0.040 - 0.110	0.067	0.060	0.020 - 0.020	0.020	0.020
AMMONIA (MG/L)	0.030 - 0.060	0.040	0.040	0.070 - 0.250	0.118	0.085	0.050 - 0.060	0.057	0.060
KJEL N (MG/L)	1.200 - 1.800	1.417	1.300	1.600 - 3.900	2.750	2.900	2.700 - 4.100	3.333	3.200
INORG N (MG/L)	0.060 - 0.170	0.090	0.070	0.110 - 0.300	0.185	0.155	0.070 - 0.080	0.077	0.080
TOTAL N (MG/L)	1.230 - 1.840	1.467	1.335	1.650 - 3.980	2.817	2.950	2.720 - 4.120	3.353	3.220
CHLRPYL A (UG/L)	8.4 - 10.7	9.5	9.5	28.9 - 325.1	177.0	177.0	107.7 - 124.0	115.8	115.8
SECCHI (METERS)	0.8 - 0.8	0.8	0.8	0.5 - 1.1	0.8	0.8	0.5 - 0.6	0.5	0.5

B. Biological characteristics:

1. Phytoplankton -

Sampling Date	Dominant Genera	Algal Units per ml
04/22/74	1. Chrysophytan flagellates	3,134
	2. Stephanodiscus sp.	1,458
	3. Chroomonas sp.	310
	4. Dactylococcopsis sp.	310
	5. Oscillatoria sp.	248
	Other genera	156
	Total	5,616
07/11/74	1. Aphanizomenon sp.	14,059
	2. Oscillatoria sp.	378
	Total	14,437
09/20/74	1. Aphanizomenon sp.	45,153
	2. Oscillatoria sp.	485
	3. Nitzschia sp.	242
	Total	45,880

2. Chlorophyll a -

Sampling Date	Station Number	Chlorophyll a (µg/l)
04/22/74	1	10.7
	2	8.4
07/11/74	1	28.9
	2	325.1
09/20/74	1	107.7
	2	124.0

C. Limiting Nutrient Study:

1. Autoclaved, filtered, and nutrient spiked -

a. April sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.015	0.093	4.5
0.050 P	0.065	0.093	4.9
0.050 P + 1.0 N	0.065	1.093	24.9
1.0 N	0.015	1.093	10.0

b. September sample -

Spike (mg/l)	Ortho P Conc. (mg/l)	Inorganic N Conc. (mg/l)	Maximum yield (mg/l-dry wt.)
Control	0.155	1.158	27.9
0.050 P	0.205	1.158	27.3
0.050 P + 1.0 N	0.205	2.158	44.3
1.0 N	0.155	2.158	40.5

2. Discussion -

The control yields of the assay alga, Selenastrum capricornutum, indicate that the potential primary productivity of East Vermillion Lake was moderately high to very high when the assay samples were taken. In both assays, there was a significant increase in yield when only nitrogen was added, but no such response occurred when only phosphorus was added. These results indicate nitrogen limitation.

The lake data support the assay findings. The mean inorganic nitrogen to orthophosphorus ratios were 7 to 1 in April, 2 to 1 in July, and 1 to 1 in September; and nitrogen limitation would be expected.

IV. NUTRIENT LOADINGS
(See Appendix E for data)

For the determination of nutrient loadings, the South Dakota National Guard collected monthly near-surface grab samples from each of the tributary sites indicated on the map (page v), except for the high runoff months of April and June when two samples were collected. Sampling was begun in October, 1974, and was completed in July, 1975.

Through an interagency agreement, stream flow estimates for the year of sampling and a "normalized" or average year were provided by the South Dakota District Office of the U.S. Geological Survey for the tributary sites nearest the lake.

In this report, nutrient loads for sampled tributaries were calculated using mean annual concentrations and mean annual flows. Nutrient loads for unsampled "minor tributaries and immediate drainage" ("ZZ" of U.S.G.S.) were estimated using the mean concentrations in East Fork Vermillion River at station A-2 and the mean annual ZZ flow.

No known wastewater treatment facilities impacted East Vermillion Lake during the sampling year.

A. Waste Sources:

1. Known municipal - None
2. Known industrial - None

B. Annual Total Phosphorus Loading - Average Year:

1. Inputs -

Source	kg P/ yr	% of total
a. Tributaries (non-point load) -		
Vermillion River	525	79.5
b. Minor tributaries & immediate drainage (non-point load) -	90	13.6
c. Known municipal STP's - None	-	-
d. Septic tanks* -	5	0.8
e. Known industrial - None	-	-
f. Direct precipitation** -	40	6.1
Total	660	100.0

2. Outputs -

Lake outlet - Vermillion River 120

3. Net annual P accumulation - 540 kg.

* Estimate based on five lakeshore dwellings and one picnic area; see Working Paper No. 175.
** See Working Paper No. 175.

C. Annual Total Nitrogen Loading - Average Year:

1. Inputs -

Source	kg N/yr	% of total
a. Tributaries (non-point load) -		
Vermillion River	5,140	60.2
b. Minor tributaries & immediate drainage (non-point load) -	890	10.4
c. Known municipal STP's - None	-	-
d. Septic tanks* -	90	1.1
e. Known industrial - None	-	-
f. Direct precipitation** -	2,410	28.3
Total	8,530	100.0

2. Outputs -

Lake outlet - Vermillion River 3,655

3. Net annual N accumulation - 4,875 kg.

D. Non-point Nutrient Export by Subdrainage Area:

Tributary	kg P/km^2/yr	kg N/km^2/yr
Vermillion River	<1	6

* Estimate based on five lakeshore dwellings and one picnic area; see Working Paper No. 175.
** See Working Paper No. 175.

E. Yearly Loads:

In the following table, the existing phosphorus loadings are compared to those proposed by Vollenweider (Vollenweider and Dillon, 1974). Essentially, his "dangerous" loading is one at which the receiving water would become eutrophic or remain eutrophic; his "permissible" loading is that which would result in the receiving water remaining oligotrophic or becoming oligotrophic if morphometry permitted. A mesotrophic loading would be considered one between "dangerous" and "permissible".

Note that Vollenweider's model may not be applicable to water bodies with short hydraulic retention times.

	Total Phosphorus		Total Nitrogen	
	Total	Accumulated	Total	Accumulated
grams/m^2/yr	0.30	0.24	3.8	2.2

Vollenweider phosphorus loadings ($g/m^2/yr$) based on mean depth and mean hydraulic retention time of East Vermillion Lake:

"Dangerous" (eutrophic loading)	0.22
"Permissible" (oligotrophic loading)	0.11

V. LITERATURE REVIEWED

Murphey, Duane G., 1974. Personal communication (lake morphometry). SD Dept. of Environ. Protection, Pierre.

Vollenweider, R. A., and P. J. Dillon, 1974. The application of the phosphorus loading concept to eutrophication research. Natl. Res. Council of Canada Publ. No. 13690, Canada Centre for Inland Waters, Burlington, Ontario.

Schmidt, Artwin E., 1967. Limnology of selected South Dakota lakes. MS thesis, SD St. U., Brookings.

VI. APPENDICES

APPENDIX A

LAKE RANKINGS

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4601	LAKE ALBERT	0.321	0.170	489.111	106.289	9.200	0.019
4602	ALVIN LAKE	0.067	0.970	442.833	[illegible].700	9.400	0.017
4603	ANGOSTURA RESERVOIR	0.019	0.160	423.333	3.717	13.000	0.005
4604	BRANT LAKE	0.194	0.130	432.833	34.150	11.800	0.113
4605	*LAKE BYRON	0.443	0.370	488.333	149.350	9.000	0.146
4606	CLEAR LAKE	0.027	0.075	430.167	11.983	8.800	0.009
4607	CLEAR LAKE	1.400	0.270	495.333	691.000	7.000	0.468
4608	COCHRANE LAKE	0.037	0.150	446.000	15.683	15.000	0.008
4609	COTTONWOOD LAKE	0.685	0.265	490.333	112.017	8.600	0.417
4610	DEERFIELD RESERVOIR	0.033	0.080	303.333	3.650	15.000	0.022
4611	ENEMY SWIM LAKE	0.037	0.085	442.600	14.200	8.200	0.013
4612	LAKE HERMAN	0.340	0.155	485.000	58.733	8.600	0.174
4613	ST JOHN LAKE	0.349	0.080	489.400	120.880	9.800	0.025
4614	LAKE KAMPESKA	0.220	0.105	468.889	20.567	8.200	0.128
4615	MADISON LAKE	0.259	0.090	445.555	22.578	14.000	0.107
4616	LAKE MITCHELL	0.099	0.085	465.833	14.883	13.600	0.015
4617	LAKE NORDEN	0.256	0.165	488.667	46.800	10.000	0.050
4618	OAKWOOD LAKE EAST	0.146	0.175	487.000	113.600	10.000	0.009
4619	OAKWOOD LAKE WEST	0.181	0.135	485.833	159.667	9.600	0.021
4620	PACTOLA RESERVOIR	0.011	0.070	248.444	1.478	11.000	0.006
4621	PICKEREL LAKE	0.049	0.095	439.833	15.833	9.600	0.009
4622	LAKE POINSETT	0.115	0.315	468.444	40.211	10.000	0.023
4623	LAKE RED IRON SOUTH	0.042	0.110	430.333	6.883	7.600	0.010
4624	RICHMOND LAKE	0.187	0.150	410.000	18.467	10.000	0.144
4625	ROY LAKE	0.034	0.070	431.600	13.333	11.000	0.010
4626	SAND LAKE	0.489	0.110	471.800	65.790	12.800	0.288
627	SHERIDAN LAKE	0.053	0.105	394.000	15.433	15.000	0.016
	STOCKADE LAKE	0.233	0.150	432.000	25.400	15.000	0.109

LAKE DATA TO BE USED IN RANKINGS

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P
4629	LAKE VERMILLION	0.211	0.100	472.833	100.800	9.200	0.092
4630	WALL LAKE	0.194	0.160	441.667	55.267	7.400	0.076
4631	WAUBAY LAKE NORTH	0.098	0.145	469.555	127.033	11.400	0.023

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4601	LAKE ALBERT	20 (6)	20 (6)	10 (3)	23 (7)	68 (20)	60 (18)	201
4602	ALVIN LAKE	67 (20)	0 (0)	57 (17)	90 (27)	63 (19)	63 (19)	340
4603	ANGOSTURA RESERVOIR	97 (29)	30 (9)	87 (26)	93 (28)	20 (6)	100 (30)	427
4604	BRANT LAKE	40 (12)	53 (16)	70 (21)	47 (14)	27 (8)	23 (7)	260
4605	LAKE BYRON	10 (3)	3 (1)	17 (5)	7 (2)	73 (22)	13 (4)	123
4606	CLEAR LAKE	93 (28)	93 (28)	83 (25)	83 (25)	77 (23)	90 (27)	519
4607	CLEAR LAKE	0 (0)	10 (3)	0 (0)	0 (0)	100 (30)	0 (0)	110
4608	COCHRANE LAKE	83 (25)	40 (11)	50 (15)	67 (20)	5 (0)	93 (28)	338
4609	COTTONWOOD LAKE	3 (1)	13 (4)	3 (1)	20 (6)	82 (24)	3 (1)	124
4610	DEERFIELD RESERVOIR	90 (27)	88 (26)	97 (29)	97 (29)	5 (0)	53 (16)	430
4611	ENEMY SWIM LAKE	80 (24)	82 (24)	60 (18)	77 (23)	88 (26)	73 (22)	460
4612	LAKE HERMAN	17 (5)	33 (10)	27 (8)	33 (10)	82 (24)	10 (3)	202
4613	ST JOHN LAKE	13 (4)	88 (26)	7 (2)	13 (4)	53 (16)	43 (13)	217
4614	LAKE KAMPESKA	33 (10)	65 (19)	40 (12)	57 (17)	88 (26)	20 (6)	303
4615	MADISON LAKE	27 (8)	77 (23)	53 (16)	53 (16)	13 (4)	30 (9)	253
4616	LAKE MITCHELL	60 (18)	82 (24)	47 (14)	73 (22)	17 (5)	70 (21)	349
4617	LAKE NORDEN	23 (7)	23 (7)	13 (4)	40 (12)	45 (12)	40 (12)	184
4618	OAKWOOD LAKE EAST	53 (16)	17 (5)	20 (6)	17 (5)	45 (12)	85 (25)	237
4619	OAKWOOD LAKE WEST	50 (15)	50 (15)	23 (7)	3 (1)	58 (17)	57 (17)	241
4620	PACTOLA RESERVOIR	100 (30)	98 (29)	100 (30)	100 (30)	35 (10)	97 (29)	530
4621	PICKEREL LAKE	73 (22)	73 (22)	67 (20)	63 (19)	58 (17)	85 (25)	419
4622	LAKE POINSETT	57 (17)	7 (2)	43 (13)	43 (13)	45 (12)	47 (14)	242
4623	LAKE RED IRON SOUTH	77 (23)	58 (17)	80 (24)	87 (26)	93 (28)	78 (23)	473
4624	RICHMOND LAKE	47 (14)	40 (11)	90 (27)	60 (18)	45 (12)	17 (5)	299
4625	ROY LAKE	87 (26)	98 (29)	77 (23)	80 (24)	35 (10)	78 (23)	455
4626	SAND LAKE	7 (2)	58 (17)	33 (10)	30 (9)	23 (7)	7 (2)	158
627	SHERIDAN LAKE	70 (21)	65 (19)	93 (28)	70 (21)	5 (0)	67 (20)	370
	STOCKADE LAKE	30 (9)	40 (11)	73 (22)	50 (15)	5 (0)	27 (8)	225

PERCENT OF LAKES WITH HIGHER VALUES (NUMBER OF LAKES WITH HIGHER VALUES)

LAKE CODE	LAKE NAME	MEDIAN TOTAL P	MEDIAN INORG N	500-MEAN SEC	MEAN CHLORA	15-MIN DO	MEDIAN DISS ORTHO P	INDEX NO
4629	LAKE VERMILLION	37 (11)	70 (21)	30 (9)	27 (8)	68 (20)	33 (10)	265
4630	WALL LAKE	43 (13)	27 (8)	63 (19)	37 (11)	97 (29)	37 (11)	304
4631	WAUBAY LAKE NORTH	63 (19)	47 (14)	37 (11)	10 (3)	30 (9)	50 (15)	237

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
1	4620	PACTOLA RESERVOIR	530
2	4606	CLEAR LAKE	519
3	4623	LAKE RED IRON SOUTH	473
4	4611	ENEMY SWIM LAKE	460
5	4625	ROY LAKE	455
6	4610	DEERFIELD RESERVOIR	430
7	4603	ANGOSTURA RESERVOIR	427
8	4621	PICKEREL LAKE	419
9	4627	SHERIDAN LAKE	370
10	4616	LAKE MITCHELL	349
11	4602	ALVIN LAKE	340
12	4608	COCHRANE LAKE	338
13	4630	WALL LAKE	304
14	4614	LAKE KAMPESKA	303
15	4624	RICHMOND LAKE	299
16	4629	LAKE VERMILLION	265
17	4604	BRANT LAKE	260
18	4615	MADISON LAKE	253
19	4622	LAKE POINSETT	242
20	4619	OAKWOOD LAKE WEST	241
21	4631	WAUBAY LAKE NORTH	237
22	4618	OAKWOOD LAKE EAST	237
23	4628	STOCKADE LAKE	225
24	4613	ST JOHN LAKE	217
25	4612	LAKE HERMAN	202
26	4601	LAKE ALBERT	201
27	4617	LAKE NORDEN	184
	4626	SAND LAKE	158

LAKES RANKED BY INDEX NOS.

RANK	LAKE CODE	LAKE NAME	INDEX NO
29	4609	COTTONWOOD LAKE	124
30	4605	LAKE BYRON	123
31	4607	CLEAR LAKE	110

APPENDIX B

CONVERSION FACTORS

CONVERSION FACTORS

Hectares x 2.471 = acres

Kilometers x 0.6214 = miles

Meters x 3.281 = feet

Cubic meters x 8.107×10^{-4} = acre/feet

Square kilometers x 0.3861 = square miles

Cubic meters/sec x 35.315 = cubic feet/sec

Centimeters x 0.3937 = inches

Kilograms x 2.205 = pounds

Kilograms/square kilometer x 5.711 = lbs/square mile

APPENDIX C

TRIBUTARY FLOW DATA

TRIBUTARY FLOW INFORMATION FOR SOUTH DAKOTA 05/03/76

LAKE CODE 4629 EAST VERMILLION

TOTAL DRAINAGE AREA OF LAKE(SQ KM) 1036.0

TRIBUTARY	SUB-DRAINAGE AREA(SQ KM)	NORMALIZED FLOWS(CMS) JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
4629A1	1036.0	0.0	0.0	0.057	0.311	0.283	0.142	0.142	0.085	0.057	0.028	0.0	0.0	0.092
4629A2	932.4	0.0	0.0	0.045	0.283	0.283	0.113	0.113	0.057	0.028	0.0	0.0	0.0	0.081
4629ZZ	103.6	0.0	0.0	0.028	0.057	0.028	0.028	0.028	0.0	0.0	0.0	0.0	0.0	0.014

SUMMARY

TOTAL DRAINAGE AREA OF LAKE = 1036.0
SUM OF SUB-DRAINAGE AREAS = 1036.0
TOTAL FLOW IN = 1.13
TOTAL FLOW OUT = 1.10

MEAN MONTHLY FLOWS AND DAILY FLOWS(CMS)

TRIBUTARY	MONTH	YEAR	MEAN FLOW	DAY	FLOW	DAY	FLOW	DAY	FLOW
4629A1	10	74	0.023	13	0.020				
	11	74	0.020	16	0.020				
	12	74	0.020	15	0.020				
	1	75	0.023	19	0.023				
	2	75	0.023	9	0.020				
	3	75	0.020	9	0.020				
	4	75	0.023	12	0.020				
	5	75	0.020	13	0.020				
	6	75	0.014	16	0.014	30	0.017		
	7	75	0.014	25	0.017				
	8	75	0.023	25	0.011				
	9	75	0.025						
4629A2	10	74	0.006	13	0.006				
	11	74	0.006	16	0.006				
	12	74	0.006	15	0.003				
	1	75	0.003	19	0.001				
	2	75	0.001	9	0.0				
	3	75	0.006	9	0.008				
	4	75	0.008	12	0.057	29	0.023		
	5	75	0.017	13	0.014				
	6	75	0.020	16	0.020				
	7	75	0.017	25	0.014				
	8	75	0.425	25	0.008				
	9	75	0.014						
4629ZZ	10	74	0.0						
	11	74	0.0						
	12	74	0.0						
	1	75	0.0						
	2	75	0.0						
	3	75	0.0						
	4	75	0.028						
	5	75	0.014						
	6	75	0.0						
	7	75	0.0						
	8	75	0.028						
	9	75	0.0						

APPENDIX D

PHYSICAL and CHEMICAL DATA

ST ET RETRIEVAL DATE 76/05/03

462901
43 35 25 097 10 21.0 3
LAKE VERMILLION
4607 SOUTH DAKOTA

091291

11EPALES 2111202
0014 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/22	14 45	0000	10.4		30	447		152	0.040	1.600	0.130	0.020
	14 45	0005	10.8	9.4		460		152	0.030	1.800	0.040	0.011
	14 45	0010	10.8	9.0		545		151	0.030	1.300	0.030	0.011
74/07/11	14 45	0000	24.6	8.4	42	823	9.10	146	0.070	2.200	0.060	0.100
	14 45	0005	24.5	7.8		822	9.00	142	0.150	1.600	0.110	0.106
	14 45	0014	24.3	5.8		822	8.90	148	0.250	1.600	0.050	0.124
74/09/20	14 10	0000	17.1	9.4	23	695	9.23	147	0.060	3.200	0.020K	0.094
	14 10	0015	17.1	9.2		699	9.25	149	0.060	2.700	0.020K	0.112

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/22	14 45	0000	0.083	10.7	
	14 45	0005	0.093		
	14 45	0010	0.092		
74/07/11	14 45	0000	0.221	28.9	
	14 45	0005	0.174		
	14 45	0014	0.211		
74/09/20	14 10	0000	0.254	107.7	
	14 10	0003			50.0
	14 10	0005			5.0
	14 10	0006			1.0
	14 10	0015	0.303		

K VALUE KNOWN TO BE
LESS THAN INDICATED

STORET RETRIEVAL DATE 76/05/03

462902
43 36 57.0 097 10 08.0 3
LAKE VERMILLION
46087 SOUTH DAKOTA

091291

11EPALES 2111202
0913 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00300 DO MG/L	00077 TRANSP SECCHI INCHES	00094 CNDUCTVY FIELD MICROMHO	00400 PH SU	00410 T ALK CACO3 MG/L	00610 NH3-N TOTAL MG/L	00625 TOT KJEL N MG/L	00630 NO2&NO3 N-TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P
74/04/22	15	0000	10.9		31	385		153	0.040	1.200	0.030	0.011
	15	0005	10.9	9.2		447		155	0.040	1.300	0.030	0.012
	15	0010	10.9	9.4		515		155	0.060	1.300	0.040	0.012
74/07/11	14	0000	25.6	10.2	18	825	9.30	133	0.070	3.600	0.060	0.097
	14	0005	25.5	10.0		826	9.20	135	0.100	3.900	0.080	0.103
	14	0011	25.5	10.0		826	9.10	133	0.070	3.600	0.040	0.092
74/09/20	13	0000	16.6	10.6	19	687	9.35	149	0.050	4.100	0.020K	0.087

DATE FROM TO	TIME OF DAY	DEPTH FEET	00665 PHOS-TOT MG/L P	32217 CHLRPHYL A UG/L	00031 INCDT LT REMNING PERCENT
74/04/22	15	0000	0.082	8.4	
	15	0005	0.101		
	15	0010	0.079		
74/07/11	14	0000	0.241	325.1	
	14	0005	0.281		
	14	0011	0.301		
74/09/20	13	0000	0.275	124.0	
	13	0001			50.0
	13	0003			5.0

K VALUE KNOWN TO BE
LESS THAN INDICATED

APPENDIX E

TRIBUTARY DATA

STORET RETRIEVAL DATE 76/03/04

4629A1
43 35 15.0 097 10 20.0 4
VERMILLION RIVER
46 7.5 E VRMLION LK
O/EAST VERMILLION LAKE 091291
SEC RD BRDG .1 MI S OF VERMILLION DAM
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/13	10 10		0.032	0.700	0.045	0.010	0.030
74/11/16	15 00		0.040	1.200	0.050	0.020	0.020
75/04/12	09 55		0.045	1.630	0.230	0.230	0.065
75/04/29	15 30		0.005	1.450	0.020	0.005	0.010K
75/05/13	10 00		0.005	0.900	0.020	0.020	0.080
75/06/16	12 00		0.005	1.250	0.050	0.020	0.040
75/06/30	11 30		0.005	0.700	0.040	0.030	0.040
75/07/25			0.015	2.100	0.060	0.015	0.050

K VALUE KNOWN TO BE
LESS THAN INDICATED

SHEET RETRIEVAL DATE 76/05/04

4629A2
43 40 00.0 097 10 15.0 4
VERMILLION RIVER
46 7.5 MONTROSE
T/EAST VERMILLION LAKE 091242
BRDG ON US RT 90 3.2 MI SE OF MONTROSE
11EPALES 2111204
0000 FEET DEPTH CLASS 00

DATE FROM TO	TIME OF DAY	DEPTH FEET	00630 NO2&NO3 N-TOTAL MG/L	00625 TOT KJEL N MG/L	00610 NH3-N TOTAL MG/L	00671 PHOS-DIS ORTHO MG/L P	00665 PHOS-TOT MG/L P
74/10/13	09	25	0.032	0.700	0.025	0.030	0.070
74/11/16	14	40	0.008	0.800	0.025	0.045	0.050
74/12/15	13	10	0.224	0.800	0.144	0.030	0.040
75/04/12	09	25	0.345	3.200	0.230	0.067	0.200
75/04/29	15	00	0.005	5.450	0.040	0.025	0.100K
75/05/13	09	30	0.005	1.650	0.105	0.065	0.150
75/06/16	11	30	0.005	1.250	0.035	0.140	0.210
75/06/30	11	00	0.005	0.900	0.040	0.435	0.584
75/07/25	09	25	0.040	2.700	0.085	0.340	0.440

K VALUE KNOWN TO BE
LESS THAN INDICATED